Management of Frontal Sinus Fractures

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Abstract

Fractures of the frontal sinus occur from extreme forces and are often associated with other injuries. Management of frontal sinus fractures is variable and dependent on involvement of the anterior table, posterior table, and frontal outflow tract. Severe complications can developed from poorly managed fractures, such as meningitis, mucocele, mucopyocele, and brain abscess. Surgeons should be aware of appropriate management and surgical techniques for addressing frontal sinus fractures. Herein, we review the presentation and management of frontal sinus fractures, including conservative, endoscopic, and open surgical techniques.

Keywords
- frontal sinus fractures
- patient-specific implants
- cranialization
- obliteration

The frontal sinus is the last of the paranasal sinuses to complete development, usually not reaching its final size until late teenage or early adult years.[1–4] Fractures of the frontal bone and sinuses account for an estimated 5 to 15% of all facial skeleton.[4–6] The frontal bones and frontal sinus are among the strongest bones of the facial skeleton, requiring more than 800 to 2,200 lbs of force for fracture.[4,6,7] As such, frontal fractures often accompany intracranial, orbital, or other injuries, which should not be overlooked.

The pattern of frontal sinus fracture defines its required management, whether conservative, endoscopic, or open surgical. Management differs based on whether the anterior table of the frontal bone, posterior table, or both are involved. Also, management differs based on whether the frontal outflow tract is involved or not. The initial evaluation of frontal sinus fractures should elucidate the bony extent and involvement of other structures. Physical exam should note any numbness from injury to the supraorbital and supratrochlear neurovascular bundles. Similarly, it should note any frontal nerve branch weakness. Hypoesthesia and anosmia can result from shearing of the first cranial nerve, though they can also be temporary symptoms from tissue swelling. Finally, cerebrospinal fluid (CSF) leak should be carefully evaluated for, both at the initial presentation and over time. Gold-standard imaging of frontal fractures is via a computed tomography scan without contrast, which can clearly demonstrate the extent of a fracture, involvement of anterior or posterior tables, and involvement of the sinus outflow tract.[4]

Management

There are three primary treatment goals in managing frontal sinus fractures. The first is to maintain or restore a barrier between sinus and intracranial contents. This includes managing any CSF leaks and posterior table fractures. The second is to restore (or completely remove) frontal sinus outflow. Care must be taken to monitor for and prevent mucocele formation. Finally, the third goal is to restore an appropriate cosmetic appearance of the forehead. This is more applicable to anterior table fractures, though it can also factor into fractures of both the anterior and posterior table, after the posterior table concerns have been addressed.

A key component of frontal sinus fracture management is the prevention of acute and chronic complications. Acute

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complications are those that can arise in the first 6 months after injury, typically meningitis and sinusitis.[4] Chronic complications occur more than 6 months after injury and include mucocele or mucopyocele formation, bony erosion, and brain abscesses.[4] Appropriate initial management of frontal sinus fractures can mitigate the risk of acute and chronic complications.

Conservative Options

There has been a trend in the management of frontal sinus fractures over the past couple of decades toward conservative therapy for more and more fracture types. Many surgeons support conservative management for nondisplaced fractures.[8–25] Dalla Torre et al suggest that fractures with minimal bony displacement (0–2 mm) should be observed initially, whereas fractures displaced more than 5 mm will require surgery. Moderately displaced fractures (2–5 mm) are variable case to case, but some are still best treated with observation and close follow-up.[8] All patients with frontal sinus fractures should be counseled regarding "sinus precautions," that is, avoiding behaviors that can increase blood pressure to the head or increase air pressure through the sinuses. Saline nasal rinses can help clean the nasal passageways and rinse free any blood clots; patients should avoid nose blowing and Valsalva while bony healing is occurring. In some cases, laxatives can help prevent straining with bowel movements.

Endoscopic Surgery (Indications, Goals, Types of Approaches, Complications)

Some fractures will require intervention, but may be amenable to a closed, endoscopic approach. Endoscopic surgery has become an invaluable tool to aid management of frontal sinus fractures over the past two decades. Endoscopic approaches to stent open the frontal outflow tract can allow maintenance of sinus function and avoidance of open surgery. When patients require obliteration or cranialization, however, endoscopic surgery is still a useful adjunct at the time of the open procedure to aid frontal sinus identification and determine the status of the frontal outflow tract, if in question. Finally, endoscopy is useful when revision surgery is needed; late complications of frontal sinus obliteration, for example, can be successfully managed with endoscopic frontal sinusotomy or drill out.[25]

Open Surgery

Some fracture patterns are not adequately managed with conservative or endoscopic surgery, but are better treated with open obliteration or cranialization. Fracture obstruction of the nasofrontal outflow tract has historically been a reason for open surgery.[9–11] Recent studies have challenged this idea, however; Jafari et al managed eight patients with frontal fractures obstructing the outflow tract with observation and found that seven (88%) had restored normal aeration to the frontal sinus 6 weeks after injury.[12] Whenever the normal function and flow of the frontal sinuses cannot be restored, whether identified at the time of injury or after a trial of conservative management, then open surgery with obliteration or cranialization is necessary to prevent complications of an obstructed sinus. Obliteration is also useful for severely comminuted fractures of the anterior table; posterior comminution should be managed with cranialization. Numerous studies support cranialization when there is posterior comminution, dural tears, a persistent CSF leak, or irreversible nasofrontal outflow tract involvemen.[9–11,26] Classically, cranialization has been recommended for management of posterior table fractures that are comminuted, significantly displaced, or involve more than 25% of the posterior table area.[4] Today, cranialization is still employed for large and comminuted fractures, though some fractures that are displaced but have minimal comminution are amenable to reduction and fixation, with or without obliteration. Advantages of cranialization include reducing the risk of mucocele and mucopyocele formation from retained mucosa of the frontal sinus. It also decreases the risk of CSF leak by allowing direct visualization and repair of dural tears.[4]

Technique

Open repair of frontal fractures is typically accomplished through a bi-coronal incision, elevation of a pericranial flap, and reflection of the anterior scalp inferiorly to expose the frontal bone in its entirety (►**Fig. 1A–G**). Intraoperative image-guided navigation is a useful aid to identifying the borders of the frontal sinus and avoiding aberrant entrance intracranially. Transillumination from a concurrent endoscopic sinus approach is also useful. Historically, a 6-foot Caldwell plain film was used, but endoscopic transillumination and image guidance are more common, feasible, and accurate today.[4] If the posterior table needs to be addressed, a frontal craniotomy can be created and the frontal lobes of the brain retracted. Alternatively, the anterior table of the frontal sinus can be removed en bloc to allow direct fracture access and then later replaced. Removal of the anterior table requires first peripheral release around the borders of the frontal sinus, either with a drill or osteotomes. Next, the intersinus septum must be cut to allow full removal of the anterior table, and this is best accomplished with a curved osteotome. If removed intact, the anterior table can later be resecured in its original position with one or two miniplates (1.0–1.3 mm thickness) for minimal to no cosmetic disturbance. The scalp is then closed in a layered fashion.

Obliteration

If obliteration is planned, then the entire mucosal lining of the sinus must be completely removed. This can be accomplished with cutting and diamond burrs. Any retained mucosa can cause late mucocele development,[14] so meticulous removal is important. One method to ensure complete mucosal removal is to paint the inside of the frontal sinus with blue dye and then drill away everything that is covered. Next, mucosa within the frontal outflow tract should be raised and invaginated, its superior (deep) surface then plugged with temporalis muscle or other autologous or alloplastic material. The entire sinus

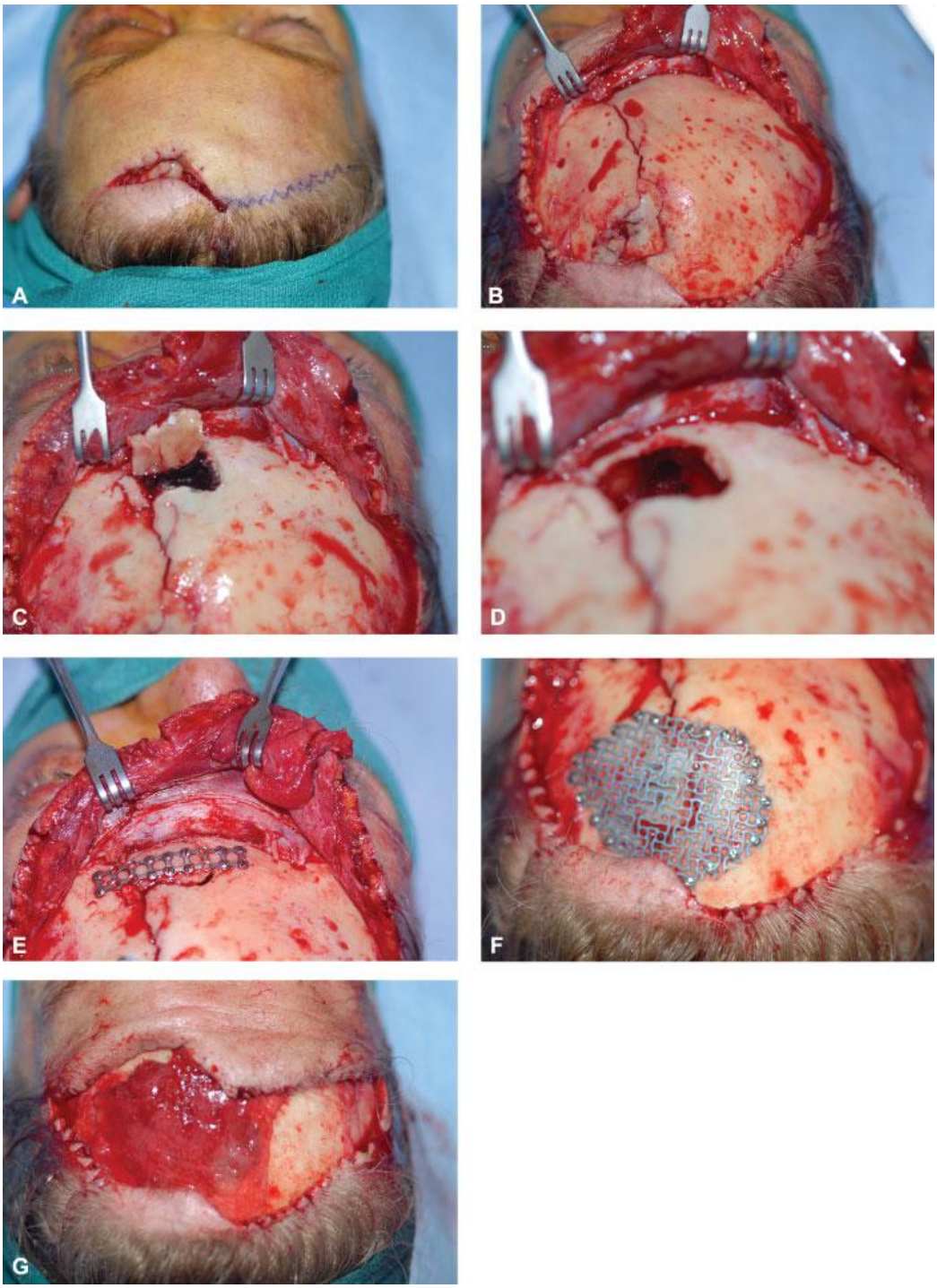

Fig. 1 (**A**) Use of prior laceration in elevation of a pericranial flap, and reflection of the anterior scalp with exposure of the frontal bone. (**B**) Exposure of full fracture extending from the calvarium to the frontal bone. (**C**) Displaced anterior table fracture fragment with exposed intrasinus mucosa. (**D**) Frontal sinus contents with visualization of intact, unobstructed, outflow tract. (**E**) Internal fixation of anterior table fragment with box plate spanning the length of the fractured segment. (**F**) Titanium mesh plate fixation of superior calvarial fracture with fragment stabilization. (**G**) Placement of pericranial flap overlying the titanium mesh plate.

should then be plugged, or obliterated, with autologous or alloplastic material, to ensure a complete seal between sinus contents anteriorly and cranial contents posteriorly is restored.

Many materials have been successfully used for obliteration of the frontal sinus, and there is no "ideal" material apparent in the literature. Autologous adipose, muscle, bone, and fascia have been commonly used. The pericranial flap, in particular, is technically easy to harvest, either as a free flap or pedicled (►**Fig. 1G**). Further, it can be anteriorly or laterally based.[20] Proponents of using a pericranial flap note that it does not require a donor site separate from the main operative site, and the flap tends to be highly vascular, leading to minimal delayed infectious complications. Further, it is distinct and separate from native bone on postoperative imaging.[20] Bone dust from the craniotomy site can also be collected and used to plug the frontal outflow tract; it typically would not provide enough material for complete sinus obliteration. Other options include lyophilized cartilage, which also obviates the need for a separate donor site. It has a tendency to ossify, calcify, and resist volume reduction over time, and studies have demonstrated minimal complications from its use. It does carry a theoretical small risk of disease transmission. Numerous alloplastic materials have also been used including Teflon, polymethylmethacrylate (PMMA), hydroxylapatite, ceramics, and others [16–18] Teflon and PMMA, however, have been associated with high rates of extrusion and are used less frequently today.

Complications specific to obliteration include skin fistula formation, mucocele and mucopyocele formation, and persistent CSF leak. Infection after obliteration is reported from 3 to 3.7%.[21,22] The true incidence of mucocele formation is difficult to estimate given poor long-term follow-up of many studies, though some studies report rates of surgical revision for mucocele as high as 7.5%.[24]

Cranialization

Cranialization involves the removal of the posterior bony wall of the frontal sinus, removal of all respiratory mucosa, and plugging of the frontal outflow tracts, essentially expanding the anterior cranial fossa and allowing the brain and dura to fill what was previously the frontal sinus. Its surgical approach is similar initially to obliteration. After removal of the osteoplastic flap, free bony segments of the posterior table are removed and the dura is inspected. Neurosurgical assistance may be needed to ensure appropriate repair of all dural injuries. A pericranial flap can be very useful to aid dural repair. Following, remaining posterior table segments are removed with rongeurs. Next, all frontal sinus mucosa is meticulously removed, similar to what is needed for obliteration described above. The posterior table edges should be drilled till they are flush with the lateral sinus walls and sinus floor. The outflow tract mucosa is elevated and inverted, then plugged with temporalis muscle or other material. Finally, the osteoplastic flap is replaced and secured with miniplates, but care should be taken to avoid strangulation of the pericranial flap pedicle, if such a flap was used.

Complications that can arise after cranialization are similar to those after obliteration. Ethmoid sinusitis has been reported at a rate of 6%.[24–27] Mucocele and mucopyocele are late complications that can develop, though their true incidence, again, is poorly reported. Rarely, life-threatening pneumocephalus can arise after cranialization. Theoretically, nose-blowing after surgery with increased intranasal pressure can push air through a frontal outflow tract that is incompletely healed or plugged, thereby creating a one-way valve into the cranial vault with air trapping. "Sinus precautions" should be routine and reinforced with patients after surgery.

Cosmetic Considerations

Anterior table fractures can leave a visually displeasing depression in the forehead of varying degrees. Correction

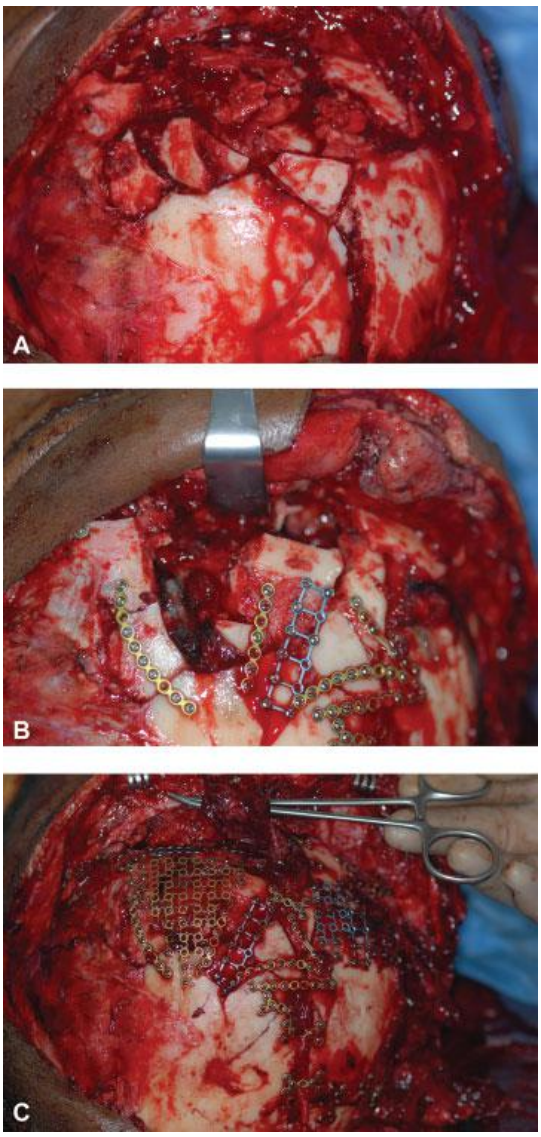

Fig. 2 (**A**) Comminuted anterior table frontal sinus fracture with multiple displaced segments. (**B**) Miniplate and box-plate fixation of anterior table frontal sinus fracture. (**C**) Multiplane reduction of comminuted fragments of frontal table.

of these fractures is often cosmetic in nature, but, nonetheless, very important to patients. Interventions to improve the appearance of anterior table fractures should be delayed at least 7 to 10 days after injury to allow for resolution of soft tissue swelling and clear delineation of the defect. Smaller, shallower defects can be managed with injectable fillers, either autologous or alloplastic. Transfer of autologous fat can be a useful, semipermanent filler, though adipose is prone to some degree of resorption over time that cannot always be accurately predicted. Microautologous fat transplantation has also been described with greater than 50% tissue retention and reliable long-term outcomes.[28–30] Calcium hydroxyapatite and poly-L-lactic acid can also be injected,[4] though patients should be aware that multiple, repeat injections over time can be necessary.

Larger and deeper defects can be improved with open reduction internal fixation (ORIF) prior to or in conjunction with fillers. A titanium mesh can be used to cover the area of fractures and smooth the contour of the forehead, secured in position with two 1.0 to 1.3 mm miniplates (►**Figs. 1E**, **F** and **2A–C**). Titanium has excellent biocompatibility producing minimal inflammation and few, if any, postoperative complications.[31–34] A titanium plate should not be placed beneath a skin-only covering, but can safely be used beneath frontalis and otherwise intact scalp.

Similarly, surgical camouflage grafting or placement of a patient-specific implant can lead to a more permanent improvement in a defect. ORIF and surgical tissue rearrangement can be approached via a coronal, pretrichial, superior eyelid, or suprabrow incision, or through a preexisting laceration. Recently, minimally invasive transcutaneous approaches have also been described that employ 5-mm stab incisions and then endoscopic-assisted work through the port.[31,32] Spinelli et al also describe a technique for addressing an isolated depressed anterior table fragment in which a screw and steel wire is used through a stab incision to reduce the bone without fixation.[33] Finally, Spindler et al describe reduction of anterior table fractures via endoscopic sinus surgery; their technique deploys a Foley catheter into the frontal sinus with subsequent balloon expansion to reduce the depressed segment.[34]

Patient-Specific Implants

The development and use of patient-specific, prefabricated implants for precise and accurate reconstruction has vastly expanded over the past decade, and these techniques are useful in addressing anterior and posterior table fractures of the frontal bone. Recently, Franz et al[35] virtually preplanned osteotomy sites required to access the frontal sinus and other areas of the facial skeleton and successfully validated the technique; such planning protocols can decrease operative times and may replace historic methods of entering the frontal sinus (transillumination, 6-foot Caldwell, etc.). Patient-specific prefabricated implants have also been used for anterior table fractures; benefits include reduced operative time and improved cosmesis.[36,37]

Conclusion

Overall, frontal sinus fracture management can vary from conservative observation with sinus precautions to open cranialization. ►**Fig. 3** presents a management algorithm to aid decision making. Fractures of the posterior table

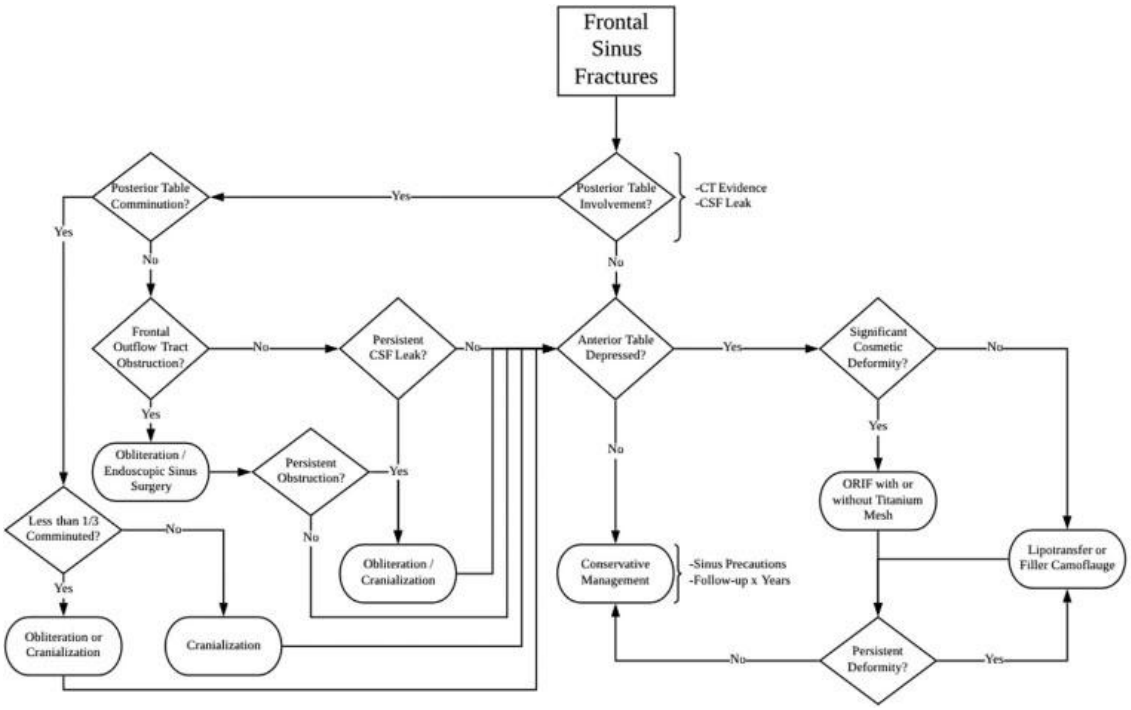

Fig. 3 Algorithm for the management of frontal sinus fractures.

should be addressed first, either with endoscopy, obliteration, or cranialization. A trial of conservative therapy is also warranted for fractures without CSF leak, severe comminution or displacement, or outflow tract obstruction. In some cases, an initial trial of conservative therapy is worthwhile, but a persistent CSF leak can become apparent as swelling abates, then necessitating surgical management. Severely depressed anterior commissure fractures should be surgically corrected with reduction of bone components or placement of a titanium mesh. Following, minor deformities can be addressed with lipotransfer or fillers. All patients should be counseled on the late complications of frontal sinus fractures and should be followed for several years after injury.

Conflict of Interest
None.

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